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1395/1394 SERIES

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1395/1394
SERIES

THERMAL CONVERTERS

BALLANTINE LABORATORIES, INC.

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WARRANTY

All Ballantine Laboratories, Inc. products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, except for vacuum tubes and batteries, or, in the case of certain major components listed in the instruction manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

NOTE

The thermoelement in your converter is a precise and sensitive device. Caution is advised on all test setups to avoid any overload of the heater or excess voltage between the couple output and heater since these failure modes are not covered by the warranty. Each thermal converter is fully aged inspected tested and certified by Ballantine engineers and a calibration record is included with every unit.

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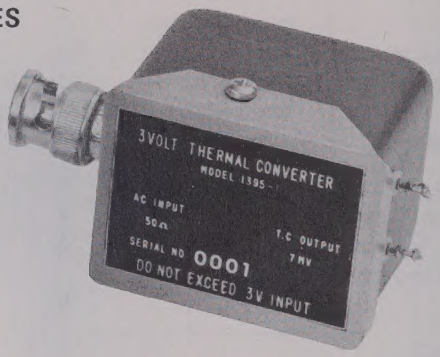
1395-( ) SERIES



1395A-( ) SERIES

Figure 1-1. 1395 Series Thermal Converter

1395 SERIES THERMAL CONVERTERS

SECTION 1. GENERAL INFORMATION

1-1. PURPOSE

The Ballantine Thermal Converters (figure 1-1) convert complex ac input signals to dc voltages, accurately proportional to the rms value of the input. All models essentially have a flat response from 5 Hz to 10 MHz.

Typical applications of the thermal converters include:

a. Calibration of ac and rf voltmeters.

b. Frequency response measurements of signal generators, amplifiers and detectors.

c. Power measurements of complex waveforms in 50 ohm systems. Converter output voltage is proportional to true input power.

Table 1-1. Calibration Uncertainty

Frequency Response checked with a standard converter traceable to NBS. Voltages measured at a point equivalent to the center of a BNC Tee Type UG 274B/U connected to the converter.

Frequency Range	Comparison/ to Standard	Reference Standard Uncertainty
DC, 5 Hz to 20 Hz	within ± 0.05%	± 0.12%
DC, 20 Hz to 20 kHz	within ± 0.01%	± 0.02%
DC, 20 kHz to 50 kHz	within ± 0.01%	± 0.03%
DC, 50 kHz to 1 MHz	within ± 0.01%	± 0.06%
DC, 1 MHz to 10 MHz	within ± 0.05%	± 0.12%

1-2. SPECIFICATIONS

Voltage Ranges:

Model	Max. Input Voltage RMS	Max. Input Voltage Peak
1395A-0.4/1395-1	0.45 volts RMS	0.75 volts peak
1395A-1/1395-2	1 volt RMS	1.50 volts peak
1395A-3/1395-3	3 volts RMS	4.50 volts peak
1395A-6	6 volts RMS	9.00 volts peak

RMS voltage is continuous maximum equivalent to dc heating value. Peak voltage at 30% maximum duty factor and represents absolute maximum value for recurrent or non recurrent input signals with on time < 1 ms.

Input Resistance: 50Ω ±0.15Ω dc and nominally constant beyond 10 MHz.

Calibrated Frequency Range: DC and 5 Hz to 10 MHz.

Usable Frequency Range: Dc and 5 Hz to greater than 100 MHz.

Thermocouple Characteristics (at 23°C ±1°C):

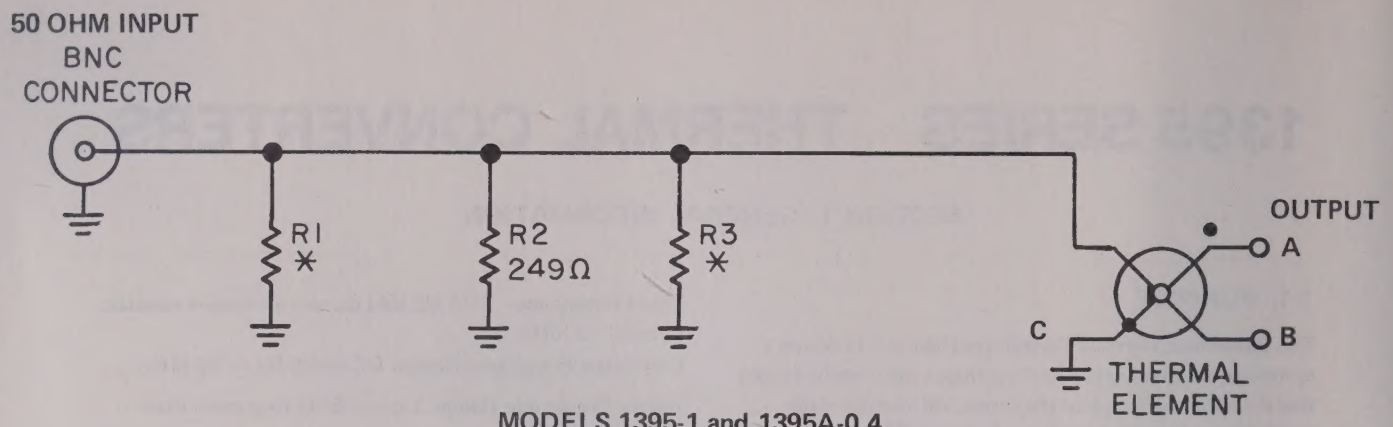
Nominal heater current	5 mA
Maximum safe heater current, 30% duty cycle on < 1 ms	7.5 mA
Couple output voltage (open circuit)	7 mV ± 12% at nominal heater current
Couple output impedance	less than 12 Ω
Couple resistance	8 Ω ± 10%
Maximum AC/DC reversal error	0.05%
Temperature coefficient	Nominally 2000 ppm/°C
Couple output voltage to heater (ground)	Normally should not exceed ± 10 volts Absolute maximum ± 50 V peak

Environment:

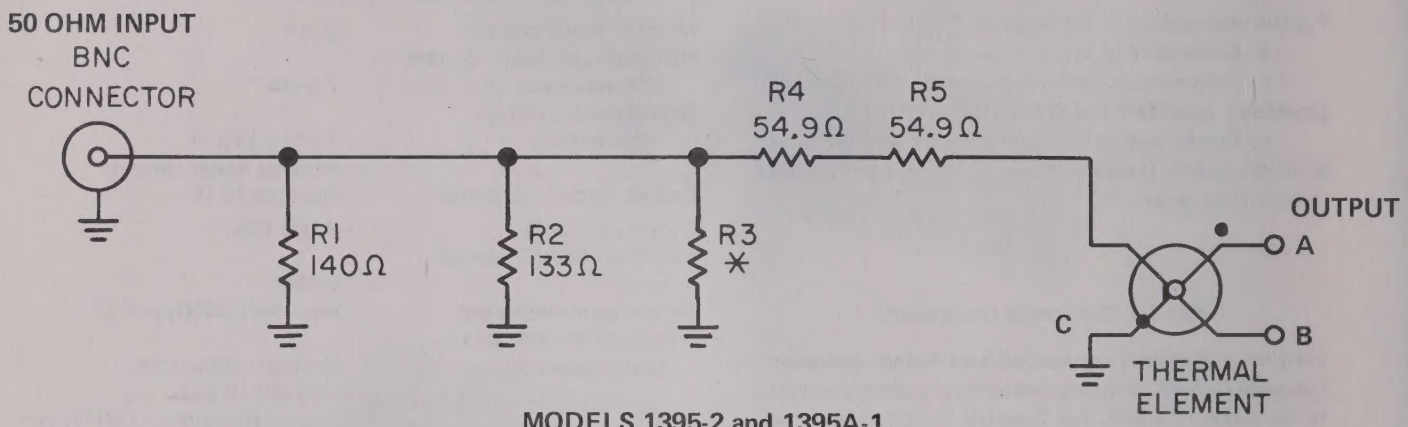
Operating temperature	4° to 40°C
Relative humidity	0 to 90%
Altitude	to 10,000 feet

Mechanical:

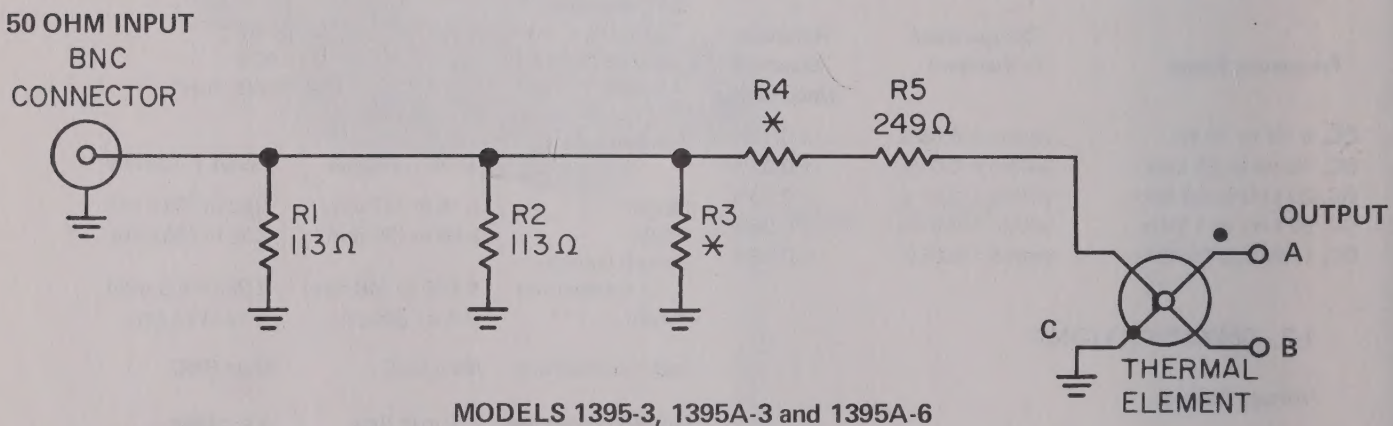
	1395 ( ) Series	1395A ( ) Series
Height	1.44 in (37 mm)	1.13 in (32 mm)
Depth	1.50 in (39 mm)	1.38 in (36 mm)
Length (exclus. of connectors)	1.875 in (48 mm)	2.25 in (58 mm)
Weight	2.4 oz (68 gm)	4 oz (112 gm)
Input connectors	Male BNC	Male BNC
Output connectors	2 Turret lugs	3 pin Male Receptacle Type MS 3102A-10SL-3P
Optional Mating connector	——	3 pin Female Type MS3106A-10SL-3S Ballantine Part No. 31100020A



MODELS 1395-1 and 1395A-0.4



MODELS 1395-2 and 1395A-1



MODELS 1395-3, 1395A-3 and 1395A-6

NOTES:

1. R4 and R5 may be combined as a single series resistor.
2. Output leads may contain ferrite beads to minimize conduction of RF interference to the output measuring instrumentation.
3. Resistors and thermocouples must be replaced as a complete set if unit is to meet full specifications.
4. 1395A-( ) Thermal Converters have a three pin output connector.
5. 1395-( ) Thermal Converters use turret lugs as output connectors.

* Selected Resistor

Figure 2-1. Schematic Diagrams

SECTION 2. CIRCUIT DESCRIPTION

2-1. GENERAL

A 90Ω UHF thermoelement which contains a heater filament and a thermoelectric junction, comprise the basic circuit of the thermal converter (figure 2-1). The ac current into the thermoelement heats the filament, and the thermoelectric junction generates a dc voltage proportional to the filament temperature. Therefore, the output voltage of the thermal converter is proportional to the input heating power. Resistors R4 and R5 limit the current through the thermoelement to 5 mA with maximum rated voltage. R1, R2 and R3 adjust the input resistance to 50Ω.

2-2. INPUT-OUTPUT RELATIONSHIP

The output voltage of the thermal converter is a function of input power. Therefore, the output varies as the square of the input. When the input is doubled, the output will be four times as great. When the input is halved, the output will drop to one-fourth.

For input changes of less than 3%, the input-output relationship is essentially linear; and the percent output change is equal to twice the percent input change. The following formula shows the relationship.

$$\% \text{ input change} = \frac{\Delta E_{dc}}{2E_{dc}} \times 100$$

where E_{dc} = thermal converter output voltage.

If the input lever is to be varied by more than 3% the actual input-output characteristic should be measured. This is best done at DC.

Since the thermal elements in the converter have a small thermal lag a ten second settling time is recommended for measurements requiring the utmost precision.

Figure 2-2 graphically illustrates the input-output relationship.

2-3. INPUT DYNAMIC RANGE

The dynamic range of Ballantine thermal converters is limited by the resolution and noise (at best about 100 nanovolts) of the system used to measure the output voltage of the couple. At maximum input level the output is only 7 mV. The conversion follows a square law relationship and the output therefore drops by 100 whenever the input is reduced by a factor of 10. Thus if 0.01% (one part in 10,000) input resolution is desired the minimum output voltage would only be 500 μ volts. This corresponds to an input voltage range somewhat greater than 3 to one. A dynamic range of 30 to one is possible when 1% resolution of input voltage (one part per hundred) is satisfactory.

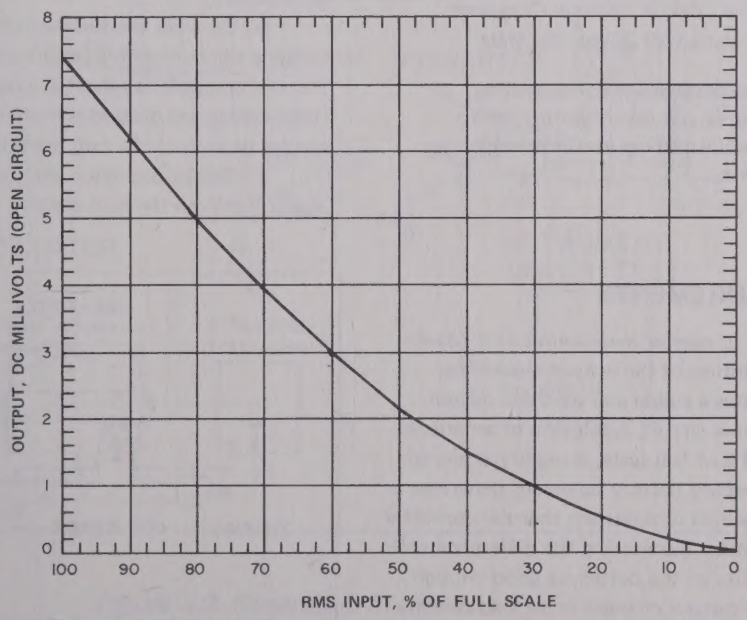


Figure 2-2. Input-Output Relationship

SECTION 3. OPERATION

3-1. PRECAUTIONS

Burnout of the thermocouple heater occurs so rapidly when the maximum peak power is exceeded that the rise in dc couple output voltage cannot be detected. Therefore it is necessary to take the following precautions to avoid overloading the thermocouple.

a. Be sure the voltage being measured is reduced to its lowest value before connecting or disconnecting the thermal converter input. Never allow intermittent wiring connections or poorly assembled connectors.

b. Provide a method for monitoring or controlling the voltage being measured by the thermal converter.

c. Do not change the frequency of the generator for voltage being measured without first reducing the voltage of the generator to its lowest value. **Caution:** *Most signal generators and oscillators produce large transient voltages when changing range.*

d. Do not allow the open-circuit dc couple voltage to exceed 7 millivolts (equivalent to 5 mA of heater current).

e. Non-sinusoidal waveforms, such as transients and pulse trains must have peak voltages which crest within the peak voltage and duty factor specifications.

f. Use precision 50 ohm attenuators ahead of the thermal converter when larger voltages or unknown signals are to be measured.

g. When larger voltages are to be measured than 6 V RMS or when higher impedance thermal converters inputs are required use

(1) The Ballantine 1600A (ATS) Auto-Balance transfer standard.

(2) The Ballantine Coaxial Thermal Converter Series 1394 200 ohms/volt DC to 100 MHz

h. Never exceed the breakdown voltage rating of ± 50 volts between couple and heater during set up of instrumentation and while making measurements. Ground all instrumentation.

3-2. OUTPUT MEASUREMENTS

The reliability of thermal converter measurements is based on the accuracy and resolution of the output measuring circuit. Figure 3-1 illustrates a stable and sensitive output monitoring circuit. With this circuit, resolution of an output change of 1.5 μV, or 0.01% of full scale, is readily achieved. The reference supply (mercury battery powered) generates a stable reference voltage, which opposes the thermal converter output with the dc null meter monitoring the difference voltage. The short term stability of the battery is good enough for the thermal converter output changes to be read directly on the null meter, without taking reference voltage drift into consideration. Another output measuring system providing stability and accuracy would be a stable high resolution digital voltmeter or differential voltmeter. To resolve an input change of 1% of full scale, the output monitor should be able to resolve 150 μV; for input changes of 0.1% of full scale, it should be able to resolve 14 μ V. Battery operated instruments are recommended to avoid grounding problems and other power line effects. It is not uncommon to make these measurements in a screen room.

When building the reference supply shown in Figure 3-1, utilize a mercury battery and wirewound resistors. Use 10 turn or 20 turn high resolution wirewound potentiometers, and a switch with contacts exhibiting low thermoelectric effects. After constructing the reference supply, mount it in a shielded container and permit the battery to age in the circuit for approximately one week. The longer the battery is allowed to age, the better its short term stability will be.

A constant ambient temperature should be maintained while making all thermal converter measurements. (25°C + 2°C is recommended) Since the thermoelement responds to the heating effect of the input signal, a change in ambient temperature would cause a change in the thermal converter output.

3-3. FREQUENCY RESPONSE MEASUREMENTS

A test setup for making accurate frequency response measurements is shown in figure 3-1. The following steps describe the measurements.

a. Set the oscillator and reference supply output levels to minimum.

b. Connect the test equipment as shown in figure 3-1 keeping the connecting cable between the oscillator and thermal converter as short as possible. Use shielded low noise cables and ground the reference voltage supply to the chassis ground of the null meter.

c. Adjust oscillator amplitude for an indication of about 7 mV on the null meter.

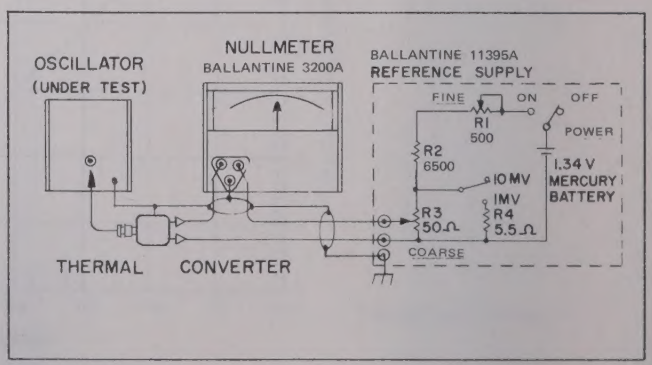


Figure 3-1. Frequency Response Measurements

CAUTION

Do not exceed the rated input of the thermal converter. Always reduce the input before changing frequency range of circuit under test. Any overload or high voltage transient may destroy the thermoelement. Ground test equipment and do not exceed couple to heater voltage rating.

d. Adjust the reference supply for a null indication within 1 μ V. Once a null is obtained, do not readjust the oscillator or reference supply outputs.

e. Change the input frequency and observe thermal converter output changes. Remember that the percent of converter output change read on the null meter equals twice the percentage input signal level change.

3-4. GENERATING AN ACCURATE CALIBRATION SIGNAL

The test setup shown in figure 3-2 provides a test signal that may be used for both frequency response and absolute value calibration at any frequency within the thermal converter range. The dc standard provides the absolute value voltage reference, and the test oscillator generates the ac calibration signal. When S1 is set to the dc position and output of the DC Voltage Standard is set to the desired calibration voltage, the reference supply is adjusted for a null indication on the Null Meter. When S1 is switched to the AC position, the oscillator output amplitude is adjusted to re-establish a null indication. This sets the RMS value of the oscillator output equal to the DC Voltage Standard output. The oscillator output signal is used for the instrument under test.

3-5. DC REVERSAL ERROR

DC inputs of opposite polarity will produce slightly different outputs from the thermal converter. This difference in thermocouple outputs for positive or negative input signals is called the DC reversal error. Sinusoidal input signals have equal energy content in positive and negative half cycles. These sine wave signals automatically average DC reversal errors in the thermocouple. Nevertheless, unidirectional signals such as pulse trains, switching transients, and sine waves with dc offset will primarily have energy content in one polarity and therefore thermal converters require DC reversal error correction. The DC reversal error is less than 0.05% and does not affect most measurements, but it should be considered to achieve maximum accuracy.

Instructions for correcting precise measurements for DC Reversal Error are given in the following calibration procedure.

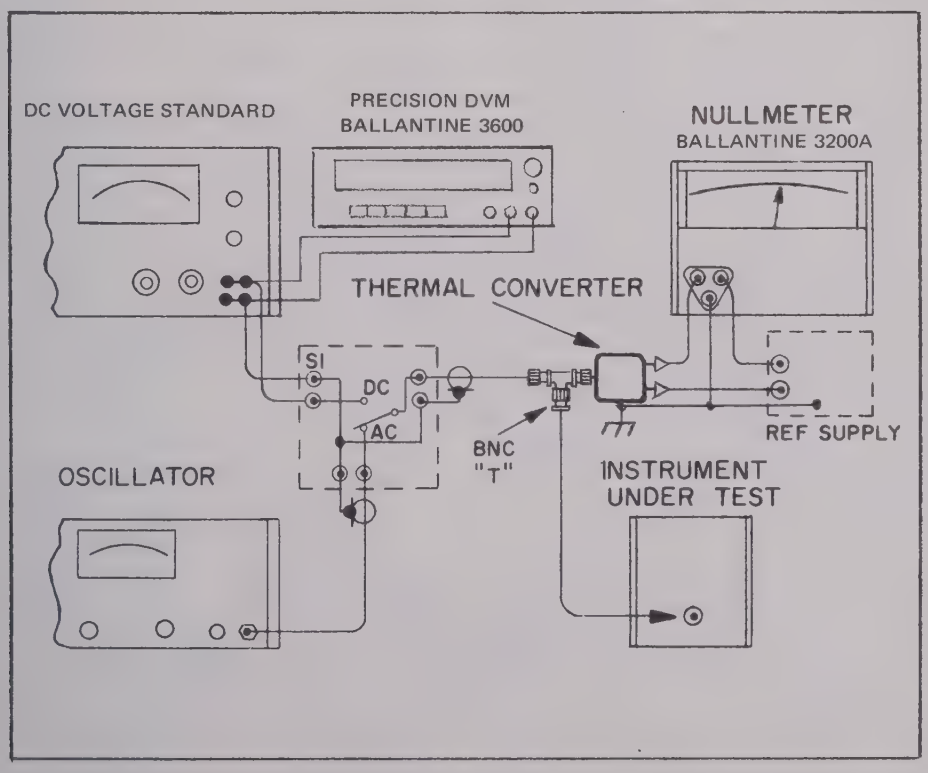


Figure 3-2. Generation of a Precise Test Signal

Table 4-1. Recommended Test Equipment

Qty.	Item	Recommended	Alternate
2	DC Null Meter/DC Micro Voltmeter 15 μvolts to 1500 volts	Ballantine 3200A	GR1807
2	Reference Supply	Ballantine 11395A	——
1	DC Voltage Standard	HP 741B (20mA)	Ballantine 421B (10 mA)
1	Precision Digital Voltmeter 100 μV resolution on 1 volt scale Accuracy ±0.01%	Ballantine 3600	DANA 5500
1	Oscillator 10 Hz to 10 MHz 3 volts into 50 Ω	HP 651B	
1	Power Supply DC, 0-10 volts, 0 to 1 amp	Power Designs 1515B	HP6213 A
1	Impedance Bridge	General Radio Type 1608A	
1	50 ohm Feed thru Termination	Ballantine 12630A	HP11048B
1	AC Voltmeter, 1 mV full scale 10 Hz to 10 MHz	Ballantine 303	Ballantine 303-09
1	BNC "T" Connector UG 274/C	Ballantine 12619A	——
1	NBS Certified Thermal Converter	Ballantine 1395A-0.4	——
1	NBS Certified Thermal Converter	Ballantine 1395A-1	——
1	NBS Certified Thermal Converter	Ballantine 1395A-3	——
1	NBS Certified Thermal Converter	Ballantine 1395A-6	——

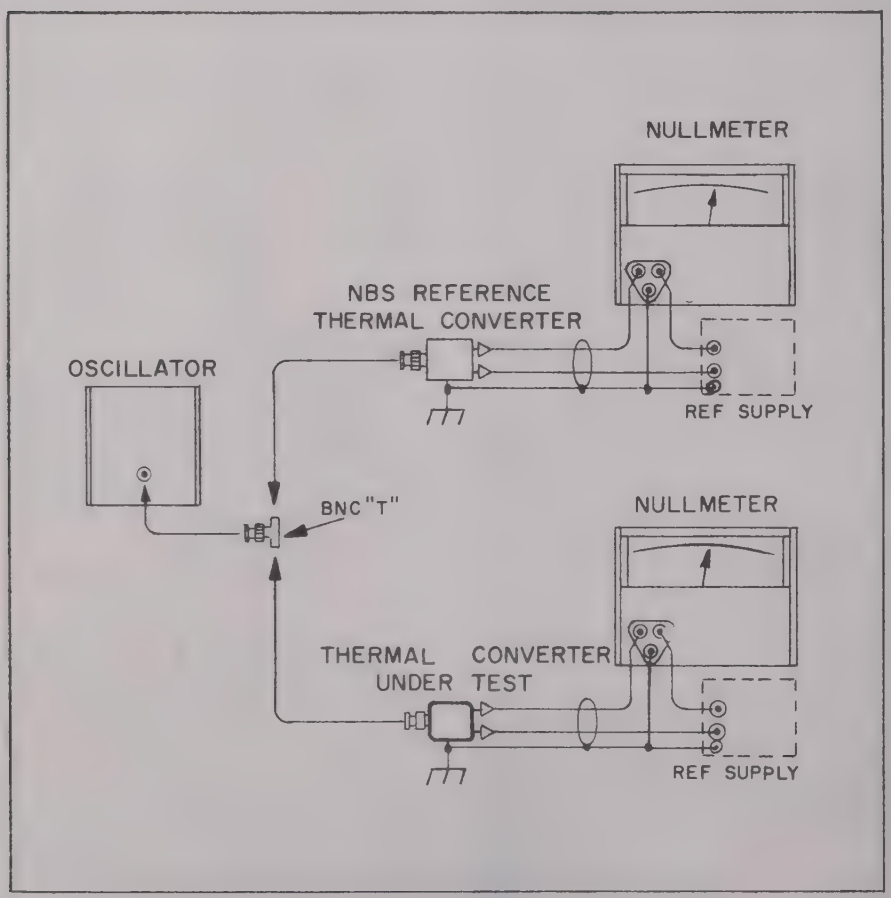


Figure 4-1. Thermal Converter Calibration

SECTION 4. CALIBRATION

4-1. CALIBRATION PROCEDURE

The steps that follow, describe a procedure for generating a 1-volt calibration signal within the thermal converter specifications. Steps c through h describe the procedure for compensating DC reversal error.

NOTE

A thermal converter is a true RMS converter responsive to the true heating value of the input signal. Average responding circuits react differently to harmonic and waveshape distortion. Calibration is normally performed with pure sinusoidal waveforms and any noise, waveshape error or harmonic distortion present will create a calibration error between the thermal converter and the instrument under test. Note that the thermal converter always measures the entire energy content (heating value) of the input calibration signal including harmonics, noise energy and non-harmonically related distortion. Use of a low distortion test oscillator is required to avoid possible calibration error of the instrument to be checked.

CAUTION

Never exceed the couple to heater breakdown voltage rating.

a. Set the test oscillator and DC Voltage Standard output level to minimum.

b. Connect the test equipment and instrument under test as shown in figure 3-2. Keep all connecting cables as short as possible. Perform these tests in a low electrical noise or shielded environment. Always ground test equipment.

c. Set S1 (in figure 3-2) to DC, and the DC Voltage Standard output to +1.000 V ±0.01%.

d. Adjust the reference supply for a null indication on the null meter within less than ±1 μV. Record the null meter indication. Once null is obtained, do not readjust reference supply output.

e. Reverse the polarity of the DC Voltage Standard output and again record the null meter reading.

f. Add the null meter reading of steps d and e.

g. Divide the sum of step f by 2. This averages the DC reversal error of the thermal converter.

h. Readjust the reference supply until the null meter indicates the average reading determined in step g.

i. Set S1 to AC and the oscillator frequency to 1 KHz. Set the oscillator output so that the null meter indication equals the indication recorded in step h. This sets the oscillator output to 1 V RMS.

j. Record the reading and error of the instrument under test. This instrument will usually be a passive device such as an AC voltmeter, wave analyzer, spectrum analyzer etc.

CAUTION

Do not change the oscillator frequency range without first lowering oscillator output. Switching transients may destroy the thermoelement.

k. Adjust the frequency to the desired test frequency. Then readjust the oscillator output amplitude for the same null meter indication obtained in step h. Record the reading and error of the instrument under test.

l. Repeat steps j and k for each test frequency desired.

4-2. THERMAL CONVERTER CALIBRATION

The test setup for calibrating a thermal converter to an NBS calibrated reference thermal converter is shown in figure 4-1. With this setup, the thermal converter can be calibrated to within ± 0.05% of the reference. The steps that follow describe the calibration procedure.

a. Set the test oscillator and both reference supply outputs to minimum.

b. Connect the test equipment up as shown in figure 4-1. Keep connecting cables to thermal converters as short as possible. Operate in a low noise or shielded environment. Consider the use of battery operated instrumentation to avoid ground loop error and power line disturbances.

c. Adjust the amplitude of the oscillator for an indication of approximately 7 mV on both null meters. Set the oscillator frequency for 1 KHz.

d. Adjust the reference supplies for a null indication on the respective null meters.

e. Change the oscillator frequency to 5 Hz.

f. Readjust the oscillator amplitude for a null indication on the null meter connected to the NBS reference thermal converter. The null meter connected to the thermal converter under thest should indicate the same as the reference null meter. If not, record the error and remember that the percent change in the thermal converter output is equal to twice the percent change in the input. (i.e. 1% change in output equals ½% input signal change).

g. Repeat steps e and f at 50 Hz, 500 Hz, 5 KHz, 50 KHz, 500 KHz, 1 MHz, 6 MHz, 8 MHz, 10 MHz. In each case, record the error.

h. Use the error data collected in steps e to g, make corrections whenever using the thermal converter. If the difference between the reference thermal converter and the thermal converter under test is greater than the specifications in the "with reference to standard" column in table 1-1, the thermal converter is not operating properly. Refer to repair instructions in paragraph 5-1.

i. The calibration of the thermal converter should be checked against an NBS reference thermal converter at least once every six months during the first year, and once a year thereafter.

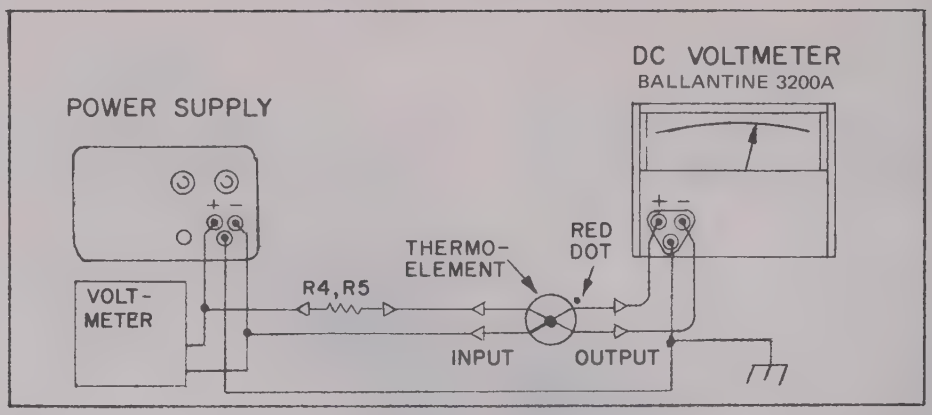


Figure 5-1. Resistor Selection

(Selection of R4 or R5 or a single equivalent resistor in series with the heater of the thermal converter.)

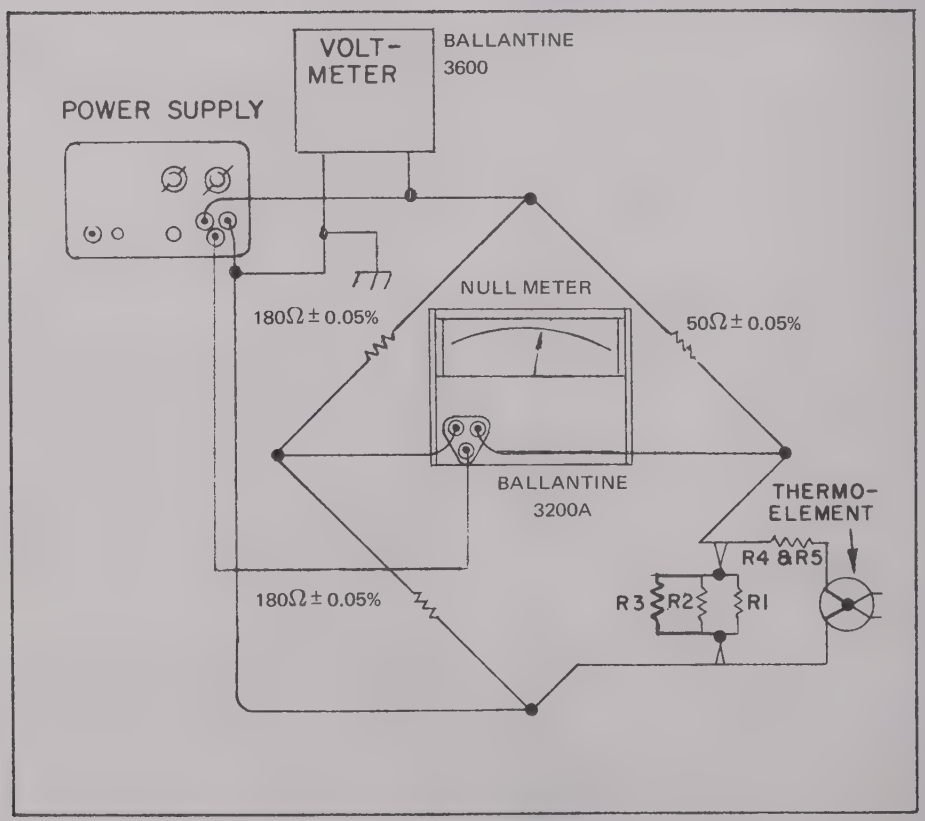


Figure 5-2. Selection of R3

SECTION 5. REPAIR AND MAINTENANCE

5-1. REPAIRING THE THERMAL CONVERTER

If the thermal converter is out of calibration below 10 MHz or it has no output, then the UHF thermoelement should be replaced. Since the values of R3 and R4 and R5 in the circuit (see figure 2-1) depend on variations in thermoelement characteristics, they must always be re-selected when the thermoelement is replaced.

5-2. SELECTION OF R4 AND R5

Current through the thermoelement is adjusted to 5 mA with a full scale input by R4 and R5. In the Model 1395A3/1395-3, R4 and R5 have a total value of about 510Ω. In the Model 1395A-1/1395-2, R4 and R5 have a total value of about 110Ω, and in the Model 1395A-0.4/1395-1, R4 and R5 are deleted. R4 and R5 should always be ½ watt (40°C) ±1% precision film resistors.

The test setup for selecting R4 and R5 is shown in figure 5-1. The power supply provides a known input, and the DC voltmeter monitors the thermoelement output. R4 and R5 are selected to adjust the thermoelement output to 6.5 mV with 90% full scale input. Proceed as follows:

a. Turn the power supply off and connect it to the thermoelement, DC voltmeter an an initial value of series resistor.

—For Model 1395A-1/1395-2 the series resistance is approximately 110Ω. This may be one single resistor or two each 54.9Ω resistors in series as R4 and R5.

—For Model 1395A-3/1395-3 the series resistance is approximately 505Ω to 570Ω. A single 510Ω resistor may be used or a 261Ω and a 244Ω resistor connected in series may be used as R4 and R5.

—For Model 1395A-6 the series resistance is approximately 1100Ω and a single resistor is usually employed.

b. Using the voltmeter as a monitor, slowly adjust the power supply output to 0.9 volts for Model 1395A-1/1395-2 or 2.85 volts for Model 1395A-3/1395-3 and 5.4 volts for Model 1395A-6.

c. Connect the voltmeter to thermoelement output and observe a 6.5 mV reading. If the output is high, increase the value of R4 or R5; if the output is low, decrease the value of R4 or R5.

An alternative method of selecting R4 and R5 is to assume that the thermoelement resistance is 90Ω and select R4 and R5 as 510Ω in series for the Model 1395A-3/1395-3, and 110Ω in series for the Model 1395A-1/1395-2 and 1100Ω for Model 1395A-6. If this method is used, the nominal 7.5 mV output may be high or low as much as 10% which is normally of no consequence.

5-3. SELECTION OF R3

a. R1 and R2 are connected in parallel as illustrated in the schematic diagram, figure 2-1.

b. R3 is selected so that when it is in parallel with R1 and R2 and with the series combination of R4, R5 (in Models 1395A-1/1395-2 and 1395A-3/1395-3 and 1395A-6) and the thermal element, produce an input resistance of 50 ±0.15 ohms.

c. This selection method is used for Models 1395A-1/1395-2, 1395A-3/1395-3 and 1395A-6 where R4 and R5 are used.

d. Resistors R1, R2, R4, and R5 are ½ watt, ±1%, (40°C), precision film resistors. Selected resistor (s), R3 may be a ¼ watt, ±1%, precision film resistor or a ½ watt carbon composition ± 5% resistor.

A bridge for selecting R3 is shown in figure 5-2. With the DC power supply drive voltage set so that the thermoelement operates at approximately its rated full scale input of 5 mA, R3 can be adjusted for null. Proceed as follows:

a. Set the power supply to off, and construct the bridge shown in figure 5-2.

b. Connect an initial value of R1 as shown in figure 5-2. For Model 1395A-6 and 1395A-3/1395-3 use two 113Ω resistors in parallel and a selected value approximately 1.82 KΩ; 1395A-1/1395-2 use a 140Ω and a 133Ω resistor in parallel and a selected value of approximately 47 KΩ; for 1395A-0.4/1395-1 use a 122Ω and a 249Ω resistor plus a selected resistor value of approximately 2.7 KΩ.

c. Adjust the power supply drive voltage to the appropriate value listed below (which will run the respective thermoelement at 60 to 80% of rated current).

1395A-0.4/1395-1	0.6 volts
1395A-1/1395-2	1.5 volts
1395A-3/1395-3	4.5 volts
1395A-6	9.0 volts

d. Vary resistor R1 to achieve a null indication on null meter. The maximum deviation from null should be as follows:

1395A-0.4/1395-1	±150 μV
1395A-1/1395-2	±375 μV
1395A-3/1395-3	±1.25 mV
1395A-6	±2.50 mV

5-4. PROCEDURE FOR AC CALIBRATION OF INPUT IMPEDANCE OF THERMAL CONVERTER

a. Connect equipment as illustrated in figure 5-3.

CAUTION

Do not connect thermal converter to be calibrated until after step discompleted.

b. Set up Impedance Bridge (General Radio 1608A) resistive impedance.

c. Adjust test oscillator for output frequency of 10 KHz.

d. Set RMS output amplitude of test oscillator for appropriate input for thermal converter to be tested (i.e. 1395A-0.4/1395-1 — 0.45 volts; 1395A-1/1395-2 — 1.0 volts; 1395A-3/1395-3 — 3.0 volts; 1395A-6 — 3 volts or 6 volts if high power low distortion oscillator is used) as indicated on AC Voltmeter, Ballantine Model 303, with a 50-ohm feedthru termination in series with voltmeter input.

e. Disconnect AC voltmeter and connect thermal converter to be tested to UNKNOWN terminals on impedance bridge.

f. Tune impedance bridge for null indicated on NULL meter of bridge. Impedance readout should be 50 ±0.15 ohms. If this readout is not obtained, perform the calibration procedures given in paragraph 4-2, and carefully redress the component in the thermal converter as shown in figure 5-4 then repeat this procedure.

5-5. INSTALLATION OF THERMOELEMENT AND RESISTORS

The spatial orientation of the components within the thermal converter is critical. Placing the components improperly may cause serious degradation of the higher frequency response. The proper component placement for each thermal converter is shown in figure 5-4.

Observe the following precautions when installing replacement thermoelement and R1 through R5.

CAUTION

Utilize an adequate heat sink when making soldering connections to the thermoelement. Excessive or extended heating will change thermoelement characteristics. Use a grounded soldering iron with 3 wire power cord to avoid exceeding the couple to heater breakdown voltage rating.

a. Keep all leads as short as possible.

b. Ensure proper component mounting in accordance with figure 5-4.

c. Avoid bending thermoelement leads any more than is absolutely necessary as excessive bending may weaken glass seal and reduce isolation.

d. Red (positive) lead should be connected to thermoelement output lead marked with a red dot.

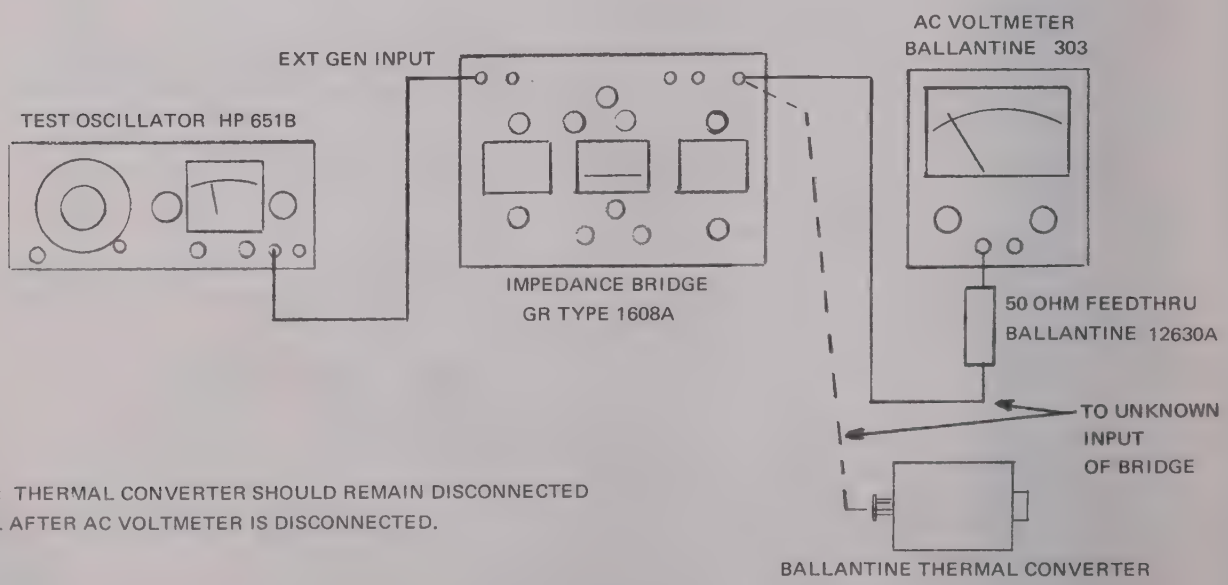
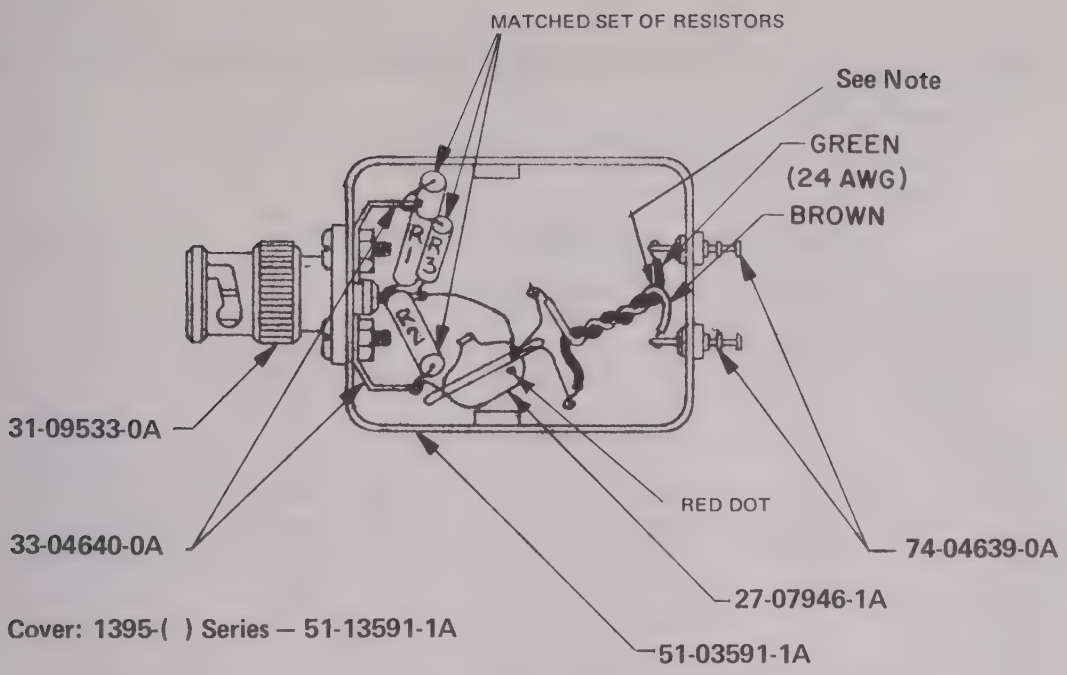
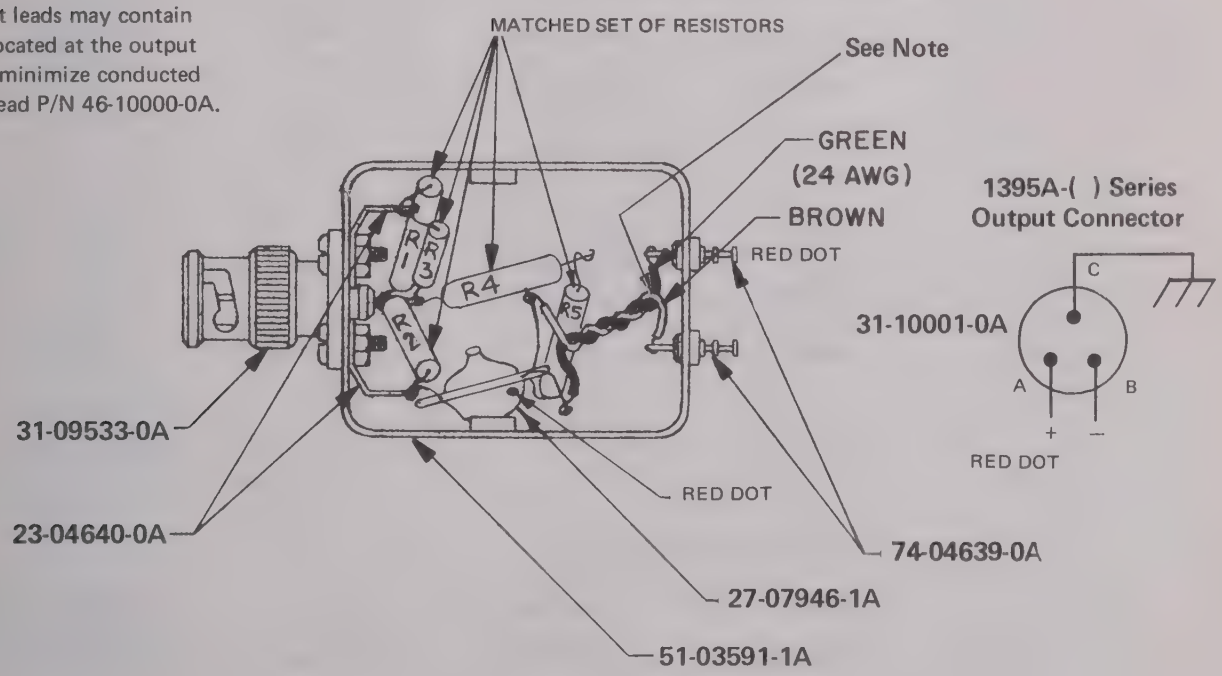


Figure 5-3. AC Calibration of Input Impedance



MODELS 1395A-0.4 and 1395-1

NOTE: Output leads may contain ferrite beads located at the output connectors to minimize conducted RFI. Ferrite bead P/N 46-10000-0A.



MODELS 1395A-1, 1395-2, 1395A-3, 1395-3 and 1395A-6

Figure 5-4. Component Location

SECTION 6. REPLACEMENT PARTS

1395 ( ) Series

Replace all resistors as set with procedure detailed in Section 5.

Ballantine P/N	Description	Mfr.	Mfr. P/N
31-09533-0A	Connector, Male BNC UG1104A/U	Pomona Electronics	2247
23-04640-0A	Lugs, Grounding	Ballantine	
74-04639-0A	Terminal Feedthru Teflon Insulation	Sealectro Corp.	
27-07946-1A	Thermoelement UHF, 5 mA	Ballantine	
51-03591-1A	Can	Ballantine	
51-13591-1A	Cover, can	Ballantine	
46-10000-0A	Ferrite bead	Stackpole	570180/7D

1395A ( ) Series

Replace all resistors as set with procedure detailed in Section 5.

Ballantine P/N	Description	Mfr.	Mfr. P/N
39-1000-11A	Can and cover assembly with input connector. Male BNC P/N P/N 31-09533-0A. Output connector MS3102A-10SL-3P P/N 31-10001-0A	Ballantine	
27-07946-1A	Thermoelement UHF, 5 mA	Ballantine	
46-10000-0A	Ferrite bead	Stackpole	570180/7D

OPTIONAL ACCESSORIES

Ballantine P/N	Description	Mfr.	Mfr. P/N
31-10002-0A	Connector, Cable 3 pin Female, MS-3106-A-10SL-3S	Amphenol	74868
31-10010-0A	Clamp, Connector/cable for MS-3106A-10SL	Ampenol	97-3057-1004
31-10020-0A	Bushing, Cable clamp protector AN3420-4	Ampenol	9779-513-4

1394 SERIES THERMAL CONVERTERS

SECTION 1. GENERAL INFORMATION

1-1. PURPOSE

The Ballantine Thermal Converters (Figure 1-1) are wide frequency range rms voltage standards. They are designed to provide accurate voltage measurements, using AC/DC transfer techniques, and precise frequency influence tests.

Typical applications include:

a. Calibration of AC and RF voltmeters.

b. Frequency response measurements of signal generators, amplifiers and detectors.

1-2. SPECIFICATIONS

Voltage Ranges:

Model	Nominal Voltage	Range and Max Input
Model 1394-0.5	0.5 volts	0.1 to 0.67 volts
Model 1394-1	1.0 volts	0.2 to 1.35 volts
Model 1394-2	2.0 volts	0.4 to 2.7 volts
Model 1394-5	5.0 volts	1 to 6.7 volts
Model 1394-10	10.0 volts	2 to 13.5 volts
Model 1394-20	20.0 volts	4 to 27 volts
Model 1394-50	50.0 volts	10 to 67 volts
Model 1394-100	100 volts	20 to 135 volts

NOTE

The 50 and 100 volt converters are specified thru 30 MHz although they are usable to 100 MHz. Other converters with nominal input voltage to 500 volts can be supplied on special order with reduced accuracy at higher frequencies.

Model 1394A - ( ) serves as above but with 3 pin output connector. (Output grounding minimizes danger of exceeding voltage breakdown between heater and couple).

Frequency Range: DC and 6 Hz to beyond 100 MHz.

Calibration Uncertainty

Frequency response checked with a standard converter traceable to NBS. Voltages measured at a point equivalent to the center of a General Radio Tee type GR 874 Series connected to the converter. Measurements reference 23°C ± 1°C.

Frequency Range	Comparison to Standard	Reference Standard Uncertainty
DC, 6 Hz to 20 Hz	within ± 0.05%	± 0.12%
DC, 20 Hz to 20 kHz	within ± 0.01%	± 0.02%
DC, 20 kHz to 50 kHz	within ± 0.01%	± 0.03%
DC, 50 kHz to 1 MHz	within ± 0.01%	± 0.06%
DC, 1 MHz to 10 MHz	within ± 0.05%	± 0.12%
DC, 10 MHz to 30 MHz	within ± 0.20%	± 0.25%
DC, 30 MHz to 50 MHz	within ± 0.5%	± 0.50%
DC, 60 MHz to 100 MHz	within ± 1.0%	± 1.50%

Input Resistance: 200 ±10 ohms per nominal volt

Input Capacitance: 5 pF nominal

Thermocouple: (23°C ± 1°C)

Nominal heater current — 5 mA

Max safe heater current — 7.5 mA

Couple Output — 7 mV ± 12% at nominal heater current

Couple Resistance — 8 ohms ± 10%

Max AC/DC Reversal Error — 0.05%

Temperature coefficient — 2000 ppm/°C

Couple output voltage to heater (ground) — Normally should not exceed ± 10 V, absolute max. ± 50 V peak

Operational Environment:

Temperature — +4°C to +40°C

Relative Humidity — 0 to 90%

Altitude — Sea level to 10,000 ft.

Mechanical Specifications:

Dimensions — 2" diam x 4 5/8" long exclusive of connectors (5.08 cm diam x 11.8 cm long)

Weight — 0.5 lbs. (230 gm)

Connectors	1394 Series	1394A Series
Input	GR874PB	GR874PB
Output	2 pin Male MS3102A-10SL-4P	3 pin Male MS3102A-10SL-3P
(Optional) mating connector	2 pin Female MS3106A-10SL-4S Ballantine P/N31073480A	3 pin Female MS3106A-10SL-3S Ballantine P/N31100020A

Figure 1-1. 1394 Series Thermal Converter

SECTION 2. CIRCUIT DESCRIPTION

Each Model 1394 Coaxial Thermal Converter consists of a stable, film type resistor in series with a high frequency thermocouple. The combination is mounted coaxially in a cylindrical tube, the diameter of which is designed to provide a nearly-constant transadmittance over a wide frequency range. Lower voltage probes have capactive compensation across the thermocouple; higher voltage probes have capacitive compensation from the body of the resistor to ground to provide as flat a frequency response as possible.

The basic schematic is shown in Figure 2-1.

To use a Model 1394 Thermal Converter it is necessary to monitor the DC couple output. The instrument used for this purpose need not be accurate; it must have resolution sufficient for the accuracy of voltage measurement being performed and short-time stability for the period of measurement.

For voltage measurements it is necessary to have a stable source of DC voltage capable of being set to the level of the AC voltage being measured. This source should be capable of delivering 5 mA into a 100 ohm to 4,000 ohm load with a 10 minute stability of 0.01% and with a precision of setability of 0.01% or better.

If reverse DC measurements are made, to eliminate the effect of reversal errors, the DC source must be operated ungrounded since one end of the thermocouple heater is grounded in the Model 1394.

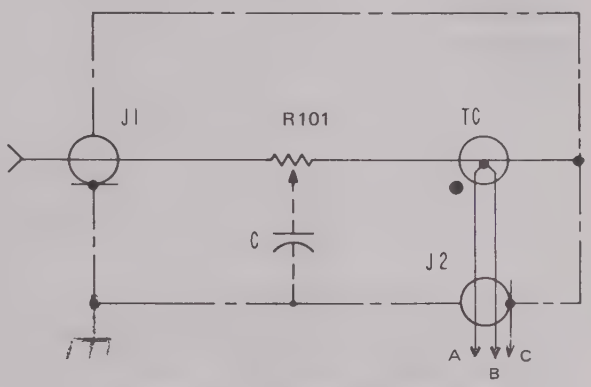


Figure 2-1. Schematic Diagram

SECTION 3. OPERATION

3-1. PRECAUTIONS

The thermocouple heater of the Model 1394 can withstand continuous overloads of 20% (to 6 mA) and momentary overload of 50% (to 7.5 mA). Overloads greater than these can result in a permanent change of thermocouple characteristics or burnout of the heater. Burnout occurs so rapidly that the rise in DC couple output cannot be detected. Therefore it is necessary to take every precaution to avoid overloading the thermocouple.

a. Be sure the voltage being measured is reduced to its lowest value before connecting or disconnecting the Model 1394 input.

b. Provide a method for monitoring or controlling the voltage being measured.

c. Do not change the frequency of the voltage being measured without first reducing the voltage to its lowest value.

d. Do not allow the open-circuit DC couple voltage to exceed 7 millivolts (equivalent to 5 mA of heater current).

e. Ground all test equipment and never exceed the breakdown voltage rating between heater and couple.

3-2. VOLTAGE MEASUREMENTS

Voltage measurements are made with the Model 1394 Coaxial Thermal Converters by using the principle of AC to DC transfer. An unknown AC voltage applied to the input of a Model 1394, chosen to have a voltage range appropriate for the measurement, will cause a rise in temperature of the thermocouple heater proportional to the RMS value of the AC voltage. This temperature rise will in turn produce a DC couple output proportional to the square of the AC voltage. If the Model 1394 is now transferred to a source of DC voltage and this source is adjusted until the DC couple output of the thermocouple is exactly the same value as it was when the AC voltage was applied, the resulting DC heater current is equal to the RMS AC heater current. Assuming a constant transadmittance of heater current to input voltage and no frequency errors in the thermocouple response, this DC input voltage is now exactly equal to the unknown AC voltage. Any measurement errors resulting from non-constant transadmittance or thermocouple frequency response are expressed as the AC/DC transfer difference. Such errors can be corrected to obtain the best measurement accuracy.

To measure the RMS value of an unknown AC voltage refer to the block diagram of Figure 3-1 and proceed as follows:

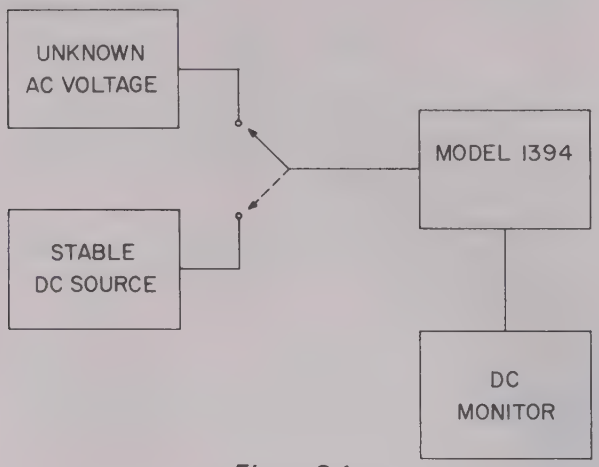


Figure 3-1

a. Select a Model 1394 whose voltage range includes the voltage to be measured. If the approximate value of the voltage is unknown, either obtain an approximate value from an auxiliary voltmeter or start the measurement process with the highest range Model 1394 and subsequently select lower range Model 1394's until the correct range is found.

b. Connect an appropriate DC monitoring instrument to the DC couple output of the Model 1394. This connection is made by a twin-contact shielded connector.

c. Reduce the level of the AC voltage to be measured to its lowest value.

d. Connect the unknown AC voltage to the coaxial input of the Model 1394.

e. Adjust the AC voltage to its desired level.

f. Note the indication of the DC monitor connected in step. b. For greatest accuracy allow 1 minute for the thermocouple to stabilize to a final output.

g. Reduce the level of the AC voltage.

h. Disconnect the input of the Model 1394 from the AC source.

i. Reduce the level of an appropriate DC source to its lowest level.

j. Connect the DC source to the coaxial input of the Model 1394.

k. Adjust the level of the DC source until the DC monitor indicates the same reading as obtained in step f. For greatest accuracy allow 1 minute for the thermocouple to stabilize to a final output.

l. Measure the value of the DC source. This value, corrected for any AC/DC transfer error, is the RMS value of the unknown AC voltage.

m. For greatest measurement accuracy, to eliminate the effects of DC reversal error in the thermocouple heater, steps i thru l should be repeated with the opposite polarity of DC. Use the average of the two DC voltages, corrected for AC/DC transfer errors, to determine the RMS AC voltage.

n. Reduce the level of the DC source to its lowest level.

o. Disconnect the input of the Model 1394 from the DC source. This completes the measurement procedure.

3-3. FREQUENCY RESPONSE MEASUREMENTS

Frequency response measurements can be made with the Model 1394 Coaxial Thermal Converters by utilizing the nearly-constant transadmittance of the Model 1394 over its frequency range. In this mode of operation the absolute level of voltage at the input of the Model 1394 is not determined by an AC to DC transfer. Instead a relative level of voltage is maintained constant at the input of the Model 1394 for all frequencies of interest. The Model 1394 can be used in this manner to determine the frequency response error of an AC voltmeter, as shown in the block diagram of Figure 3-2a. The frequency response of an amplifier can be measured as shown in Figure3-2b. Here the constant AC source could be obtained by using another Model 1394 to monitor and keep constant the input to the device under test.

3-4. Frequency Response Measurement of AC Voltmeters

A normal voltmeter calibration consists of two steps:

a. Measurement of voltmeter accuracy at midband (0.4 to 1 kHz)

b. Measurement of frequency response errors relative to midband.

The Model 1394 is very suitable for maintaining a constant AC voltage at the input of a voltmeter to determine its frequency response. Referring to Figure 3-2a proceed as follows:

a. Connect a stable AC source and the Model 1394 of proper voltage range for the measurement desired to the input of the voltmeter under test. Use short coaxial connections between the Model 1394 and voltmeter input to minimize transmission line errors.

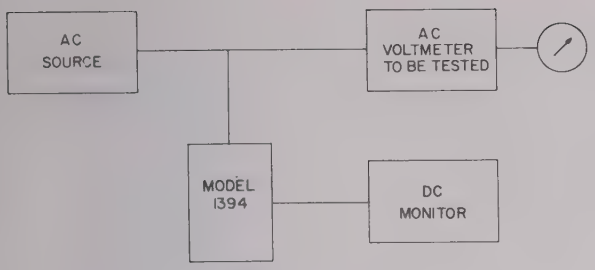


Figure 3-2a

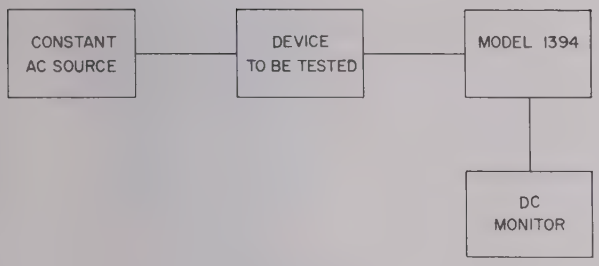


Figure 3-2b

b. Connect a suitable DC monitor to the DC couple output of the Model 1394.

c. Set the frequency of the AC source to a convenient midband frequency. This frequency should be chosen to be in a region where the voltmeter exhibits no frequency errors.

d. Adjust the level of the AC source to obtain a desired reference indication on the voltmeter under test.

e. Note the indication of the DC monitor connected in step b. For greatest accuracy allow 1 minute for the thermocouple to stabilize to a final output.

f. Reduce the level of the AC source.

g. Set the frequency of the AC source to a new frequency.

h. Readjust the level of the AC source until the DC monitor indicates the same level as in step e.

i. Note the indication of the voltmeter under test. Any change in indication from the reference level of step d, adjusted for any transfer error in the Model 1394 between the two frequencies, represents the frequency response error of the voltmeter.

j. Repeat steps f thru i for all frequencies of interest.

3-5. Frequency Response Measurement of AC Amplifiers, etc.

Referring to Figure 3-2b, proceed as follows:

a. Connect the AC source to the device to be tested. Reduce its level as low as possible.

b. Connect a Model 1394 of proper voltage range to the output of the device. Keep the connection coaxial and as short as possible to avoid transmission line errors.

c. Connect a suitable DC monitor to the DC couple output of the Model 1394.

d. Set the frequency of the AC source to a convenient midband frequency. This frequency should be chosen to be in a region where the device exhibits no frequency errors.

e. Adjust the level of the AC source to the desired value. If this is being done by the use of another Model 1394, follow the steps of 3-4 outlined above.

f. Note the indication of the DC monitor connected in step c.

g. Reduce the level of the AC source.

h. Select a new frequency of the AC source.

i. Adjust the level of the AC source to the same value as in step e.

j. Note the indication of the DC monitor. The percentage change in indication from that obtained in step f is nearly twice the percentage change in frequency response of the device (because of the approximate square-law thermocouple characteristic).
If the most accurate measurement is required the Model 1394 should be transferred to an appropriate DC source and this source adjusted to the two values necessary to produce the same DC monitor indication as in steps f and j. The change in DC source voltage, corrected for any AC to DC transfer errors in the Model 1394, represents the frequency response error of the device being tested.

k. Repeat steps d thru j for all frequencies of interest.

3-6. MEASUREMENT ERRORS

3-7. Thermocouple Errors

Ideally, one end of the heater of the thermoelement should be grounded. If the average for the two directions of direct current is used as the reference, an ungrounded DC current is required. In any case the voltage difference between the heater and thermocouple should not exceed one or two volts because of the possibility of errors from the heating of the insulating bead by small currents through it.

Since thermoelements have a frequency response which extends to 100 MHz or more, they should be used in areas of reasonably low field strength. Interference from TV stations can be particularly troublesome with low-current thermoelements. A quick check of leadborne interference is easily made by shortcircuiting the input terminals, with the connections to the standard in place as in use, but with all power supplies off. There should be no change in indication of the detector in the output circuit of the thermoelement. If the standard has output terminals for a potentiometer or galvanometer, there should be no change in the output when a capacitor (at least 1000 pF) is connected across the output terminals after a balance has been obtained in a measurement. If RF pick-up is detected it may be necessary to provide additional shielding or to use the instrument in a shielded room.

3-8. Connection Errors

Connection errors should be evaluated and minimized when an AC/DC transfer standard is used to calibrate other instruments. These errors can often be detected by changing the length and position of the leads. Short coaxial leads should be used when possible. Voltages induced in loops formed by the connections to (or within) a low-range voltmeter or to a shunted thermoelement can be significant at high frequencies, particularly when high currents are being measured. When low currents are being measured the capacitance from the lead between the standard and the test instrument to ground or other parts of the circuit can cause errors. At any frequency, differences in the impedance of the two pairs of leads from a thermal voltage converter to (1) the DC standard and (2) the point at which the DC voltage is measured must be negligible compared with the resistance of the converter. NBS AC/DC difference tests are made at the AC input posts only.

SECTION 4. MAINTENANCE, CALIBRATION & REPAIR

The Model 1394 is constructed of the best commercial components which are then carefully inspected, assembled, tested and calibrated. Because each Model 1394 contains only passive components the service life should be very long if the instrument is not overloaded or misused. NBS suggests that a recalibration interval of not less than five years is indicated for this class of voltage standard.

4-1. MAINTENANCE

No routine maintenance is required for the Model 1394 except for occasionally checking that all hardware is secure and the external surfaces are free of dirt and dust.

4-2. CALIBRATION

Because of the accuracy class of the Model 1394, it can only be calibrated by similar basic voltage standards. The most accurate source for such calibrations is the National Bureau of Standards. Calibrations to 50 kHz are available at Washington, D.C. and higher frequency calibrations at Boulder, Colorado. Ballantine Laboratories also maintains a set of Model 1394 Converters specially calibrated by NBS to use as standards for the Model 1394.

One Model 1394 can be checked against another Model 1394 if the second converter has the same nominal voltage range or differs from the first converter by no more than one voltage range. The comparison is made by connecting the two converters together with a GR 874 Tee and feeding the junction of the tee with voltages of different frequencies. Using one Model 1394 as a standard the frequency response of the other Model 1394 is measured. Any difference in response from that expected from the AC/DC transfer difference, corrected for the transfer difference of the "standard" Model 1394, is an error in calibration.

If recalibration is indicated, it is recommended that the Model 1394 be returned either to Ballantine Laboratories or the National Bureau of Standards. If this is impractical the following procedure, with numerical example, should be followed:

a. Connect the "unknown" Model 1394 to be calibrated and a "standard" Model 1394 of the same or adjacent voltage range as shown in Figure 4-1. The source should be capable of delivering both DC and AC signals at the desired frequencies to the two Model 1394's. The two DC monitors need not be accurate but should exhibit short-time stability. The DC voltmeter should be capable of measuring the DC source voltage to an accuracy commensurate with the desired calibration accuracy.

b. Apply a DC voltage to both Model 1394's, measuring this voltage with the DC voltmeter and noting the indications of the two DC monitors. In the example shown:

DC source voltage	= 2.00 V
Unknown DC Monitor	= 6.70 mV
Standard DC Monitor	= 7.00 mV

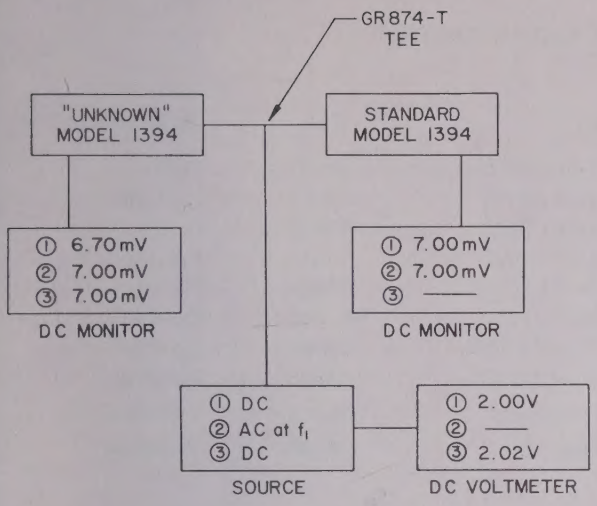


Figure 4-1

c. Apply an AC source of frequency f_1 to both Model 1394's, adjusting the level of the source to obtain the same indication on the "standard" DC monitor as in step (1) and noting the indication of the unknown DC monitor. In the example shown:

Standard DC Monitor = 7.00 mV
Unknown DC Monitor = 7.00 mV

d. Reapply the DC source, adjusting the source to obtain the unknown DC monitor indication of step c and measuring the DC source. In the example:

Unknown DC Monitor = 7.00 mV
DC source voltage = 2.02 V

e. If there is no AC/DC transfer difference at f_1 for the "standard" Model 1394, the above procedure assures that the AC input voltage to the unknown Model 1394 is the same as the DC source voltage measured in step b. If the DC source voltage measured in step d is not the same value, the percentage difference is the AC/DC transfer difference of the "unknown" Model 1394. In the example:

$$\text{AC/DC transfer difference at frequency } f_1 = \frac{2.02-2.00}{2.00} \times 100 = 1.0\%$$

f. If there is an AC/DC transfer difference at f_1 for the "standard" Model 1394, this difference must be subtracted from the AC/DC transfer difference determinded in step e. Assume in the example that the "standard" Model 1394 has a −0.2% AC/DC transfer difference at f. Then:

$$\text{Corrected AC/DC transfer difference at } f_1 = 1.0-(-0.2) = 1.2\%$$

4-3. THERMOCOUPLE REPLACEMENT

Field replacement of the thermocouple used in the Model 1394 is possible provided that the following steps are closely followed. Use only an exact replacement part, a 5 mA UHF Thermocouple with 0.05% reversal error, available from Ballantine Laboratories.

a. Remove the screw and circular nameplate at the rear of the Model 1394.

b. Carefully unsolder the two thermocouple leads that are connected to the output coaxial connector. Avoid bending these leads where they enter the glass body of the thermocouple.

c. Remove the hex post to which the nameplate was attached.

d. At the input connector of the Model 1394, remove the four mounting screws.

e. Carefully pull this input connector out of the barrel. To it will be attached the series resistor and thermocouple, together with any compensating capacitors.

f. Unsolder the thermocouple at both ends of the heater. Do not disturb the relative positions of any of the other components.

g. Cut and form the leads of the replacement thermocouple, to conform exactly to the unit just removed.

h. Solder the new thermocouple heater leads in place and reassemble, following the above procedure in reverse.

CAUTION

Use grounded soldering iron with 3 wire power cord to avoid exceeding heater to couple voltage rating.

i. If the replacement is done carefully it should not affect the AC/DC transfer difference. Follow the procedure of 4.2 to check the calibration.

NOTE

For calibration and repairs other than thermocouple replacement we recommend that the Model 1394 be returned to Ballantine Laboratories. Please include a letter describing the malfunction and/or the desired service. Pack the instrument with at least four inches of padding material all around and ship via REA, UPS, motor truck or freight to

Ballantine Laboratories Inc.
90 Fanny Road
Boonton, New Jersey USA

SECTION 5. REPLACEMENT PARTS

Model	Part No.	Symbol	Description	FSC	Supplier
1394-0.5	12-02685-0A	R101	10 Ω, 1/4W, 1%, Type MF5C	13835	Electra
1394-1	12-01511-1A	R101	110 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
1394-2	12-02688-1A	R101	310 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
1394-5	12-02689-1A	R101	900 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
1394-10	12-02690-1A	R101	1900 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
1394-20	12-02691-1A	R101	3900 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
1394-50	12-02692-1A	R101	10,000 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
1394-100	12-01508-1A	R101	20,000 Ω, 2W, 1%, Type PT-2000	03888	Pyrofilm
All Models	27-07946-1A	TC	5 mA, UHF Thermocouple	05535	Ballantine
All Models	46-10000-0A		Ferrite Beads, 57-0180-7D	78488	Stackpole
All Models	–	C	Calibration Item, Special	05535	Ballantine
All Models	3489-0A	J1	Connector, Type 874 PB	24655	General Radio
1394 ( )	7347-0A	J2	Connector, Type MS-3102-A-10SL-4P	74868	Amphenol
1394 ( )	7348-0A		Mating Connector MS3106-10SL-4S	74868	Amphenol
All Models			Connector Cable Clamp MS3057A-4A	74868	Amphenol
All Models			Connector, Bushing Protector AN3420-4	74868	Amphenol

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